# Chesapeake Bay Program Tidal Monitoring Network Design And Criteria Assessment Methodology

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# Overview of Presentation

- Spatial/Temporal Scale of Criteria Assessment
- Tidal Monitoring Network Design
- Shallow-Water Monitoring Effort
- Rationale for Criteria Assessment Methodology
- Analytical Framework for Criteria Assessment

# Objective

Define a set of tools that can be used to support criteria attainment decisions based on:

1. Magnitude of Criteria Exceedence

2. Spatial and Temporal Extent of Criteria Exceedance

3. Statistical Significance of Criteria Exceedence

# The Challenge

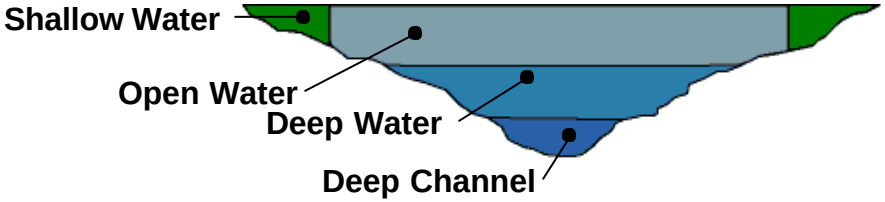
- **Magnitude**
- **Duration**
- **Frequency**
- **Space**
- **Time**

**National Research Council. 2001. *Assessing the TMDL Approach to Water Quality Management***

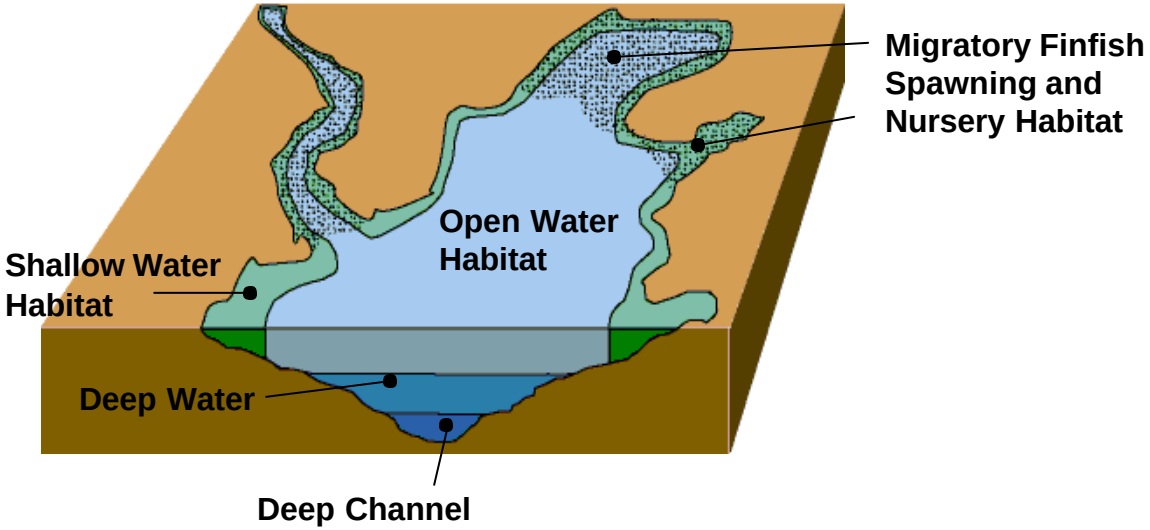
# Spatial/Temporal Scales of Criteria Assessment

# Designated Uses for Chesapeake Bay

A. Cross Section of Chesapeake Bay or Tidal Tributary



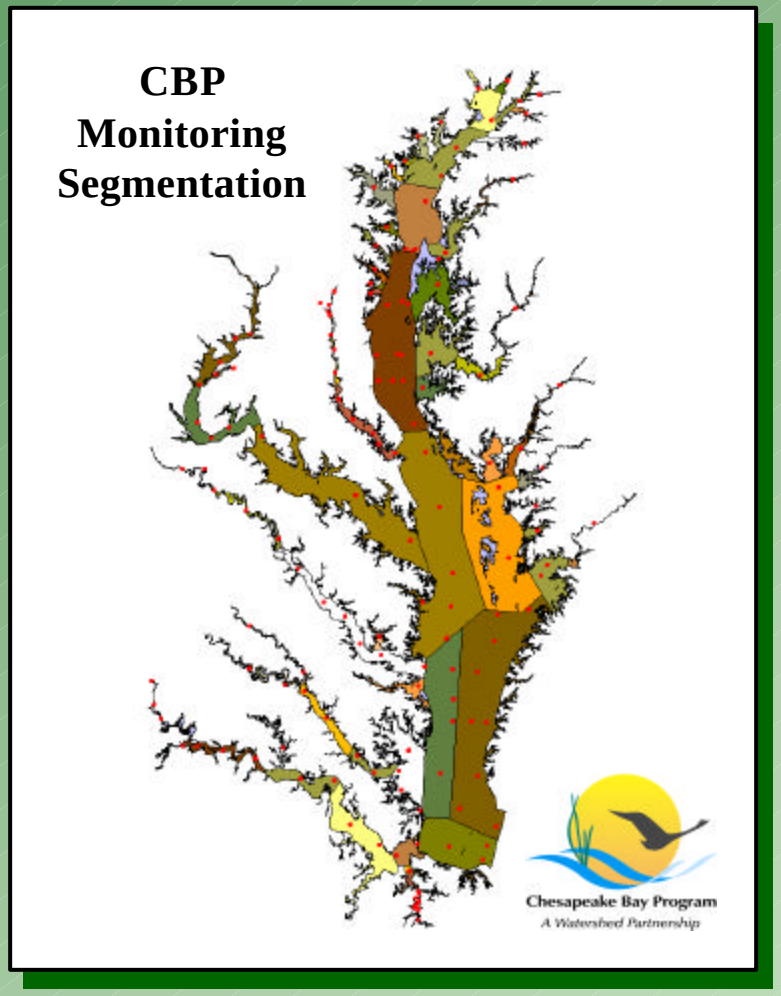

B. Oblique View of the “Chesapeake Bay” and its Tidal Tributaries



# Application of Water-Quality Criteria

| | Dissolved Oxygen | Chlorophyll a | Water Clarity |
|---|---|---|---|
| **Migratory Spawning and Nursery** | X | X | |
| **Shallow Water** | X | X | X |
| **Open Water** | X | X | |
| **Deep Water** | X | | |
| **Deep Channel** | X | | |

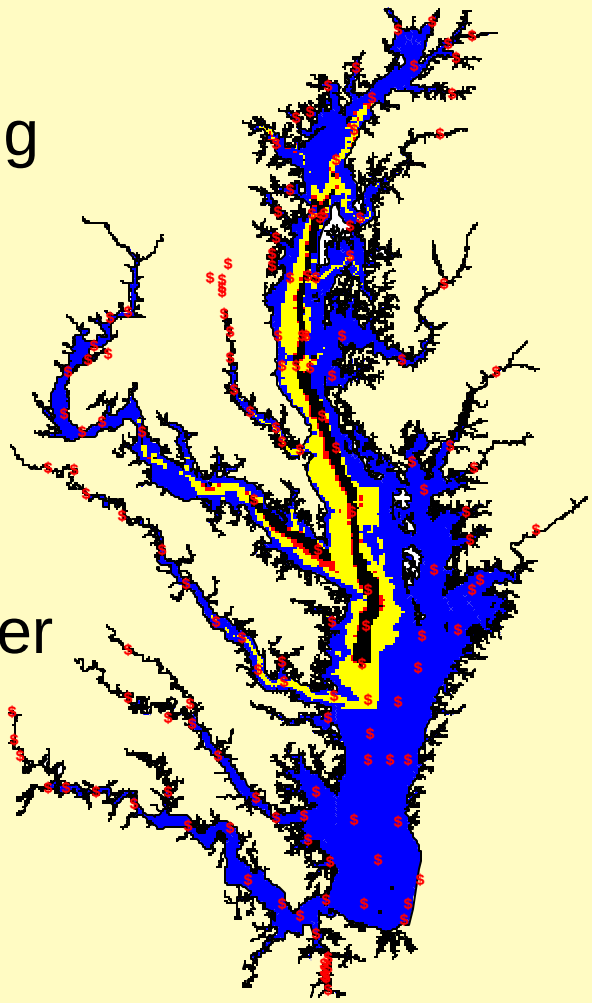
# Spatial Extent of Tidal Monitoring



Fixed-Station
Water-Quality Monitoring
Network

in Relation to the

Open Water, Deep Water
and Deep Channel
Designated Uses



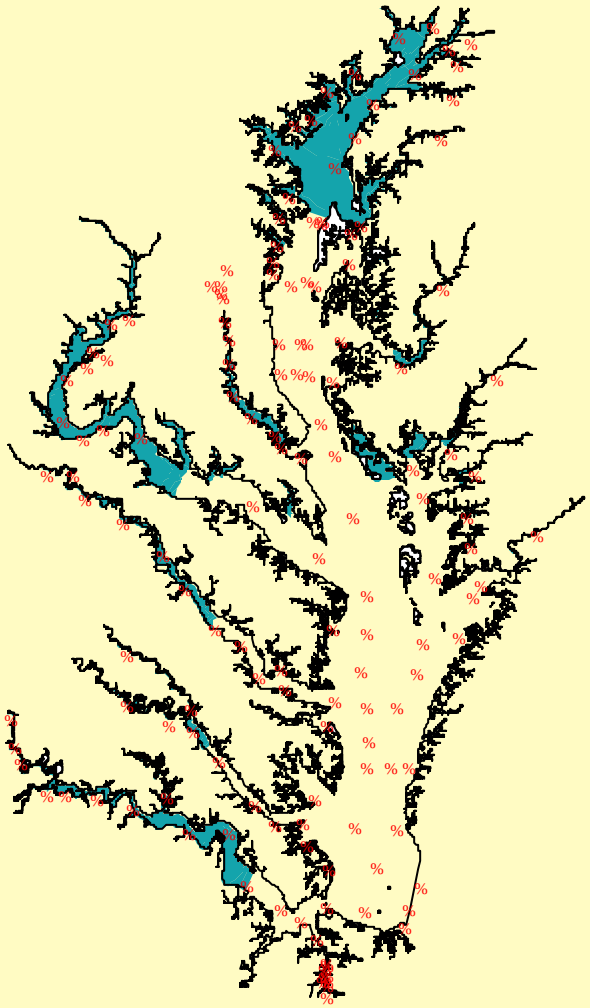
Fixed-Station

Water-Quality Monitoring Network

in Relation to the

Migratory and Spawning

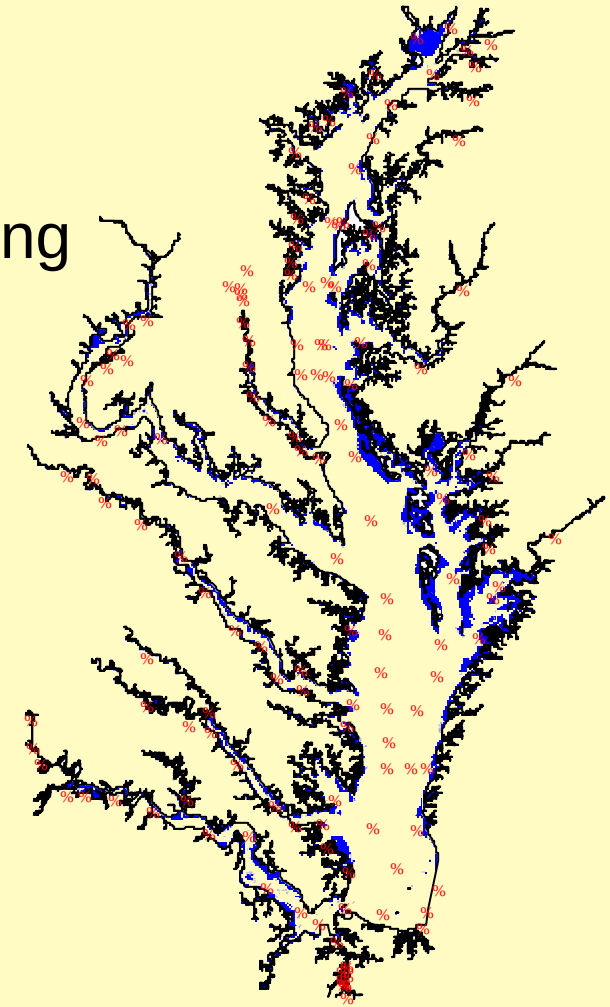
Designated Use



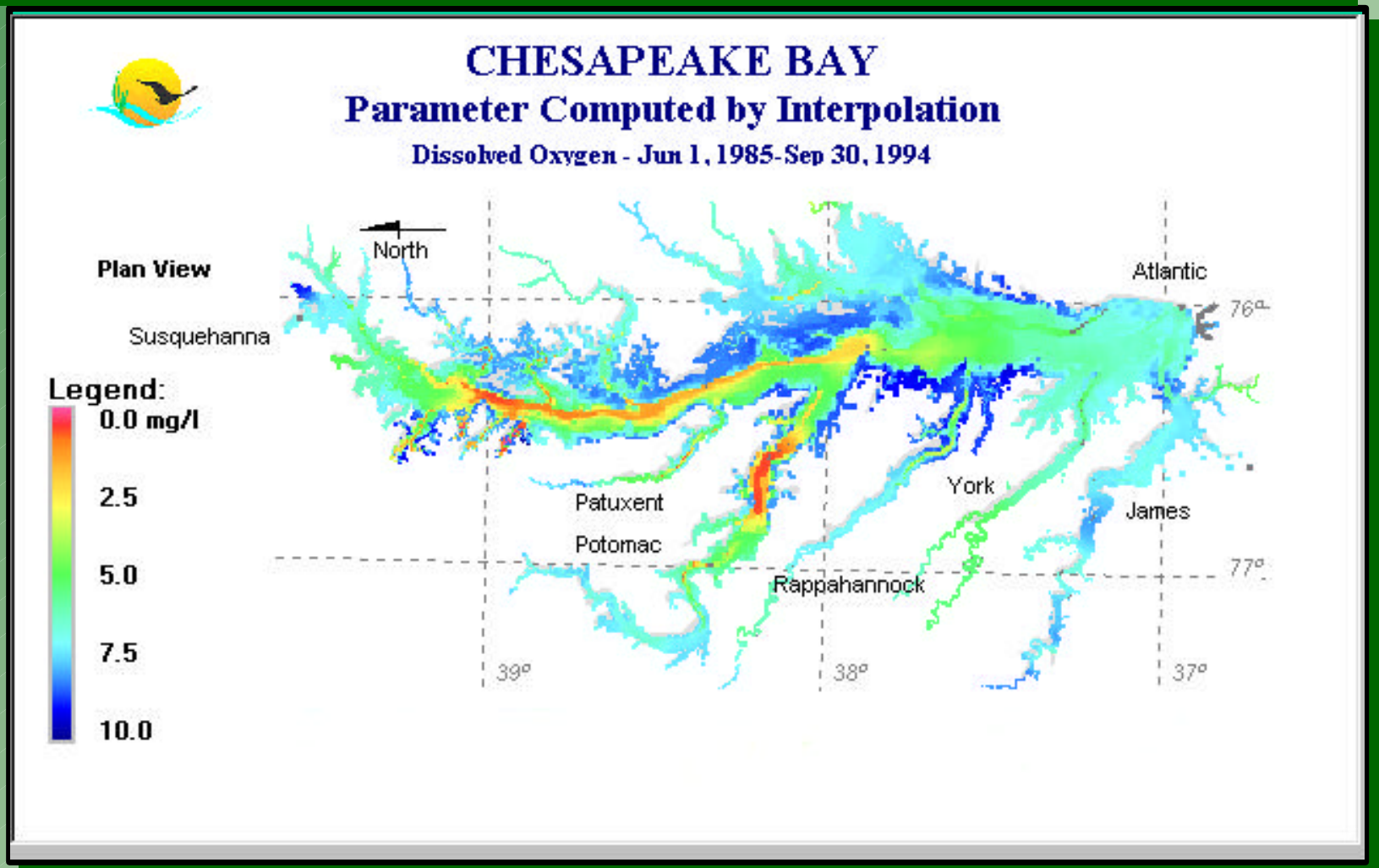
Fixed-Station
Water-Quality Monitoring
Network

in Relation to the

Shallow Water
Designated Use



# Interpretation Of Fixed-Station Data



# Tidal Water-Quality Monitoring Network Design

# Objectives of Tidal Monitoring

A. Characterization, Status

- Water-Quality Criteria
- Nutrient Reduction Goals
- Biological and Ecological Indicators

B. Temporal Changes - Long-Term Trends

C. Tidal Water-Quality Modeling

D. Understanding of Processes Related to the Attainment of Water-Quality Criteria and Other Restoration Goals

# Tidal Monitoring Framework

Objective: Characterization, Status - Criteria Attainment

| | Dissolved Oxygen | Chlorophyll a | Clarity |
|---|---|---|---|
| Migratory Spawning and Nursery | Fixed-Station Network<br>– Spatially enhance where needed<br>Buoy System – Strategically located | Fixed-Station Network<br>- To cover open-water areas<br><br>Probability-Based Network<br>- To cover shallow-water areas<br><br>DataFlow – Episodic / Strategic Basis<br><br>Remote Sensing<br>– Map the spatial extent of blooms | |
| Shallow Water | Probability-Based Network<br>– Base-line spatial extent<br>DataFlow – Episodic / Strategic Basis<br>Buoy System – Strategically located | | Probability-Based Network<br>– Base-line spatial extent<br>DataFlow – Episodic / Strategic Basis |
| Open Water | Fixed-Station Network<br>– Spatially enhance where needed<br>Buoy System – Strategically located | | |
| Deep Water | Current Fixed-Station Network<br><br>Buoy System – Strategically located | | |
| Deep Channel | Current Fixed-Station Network<br>Buoy System – Strategically located | | |

# Potential Approaches for Tidal Monitoring

A. Buoy Systems

* Potential Need - Dissolved Oxygen Criteria

B. Probability-Based Monitoring

* Potential Need - Shallow-Water Monitoring

C. Fixed-Station Monitoring

* Potential Need - All Objectives, Some Designated Uses

D. Continuous Underway Monitoring Systems

* Potential Need - Detailed Spatial Assessment

E. Remote Sensing (Aerial Over-flights, Satellite Imagery)

* Potential Need - Chlorophyll Criteria Attainment

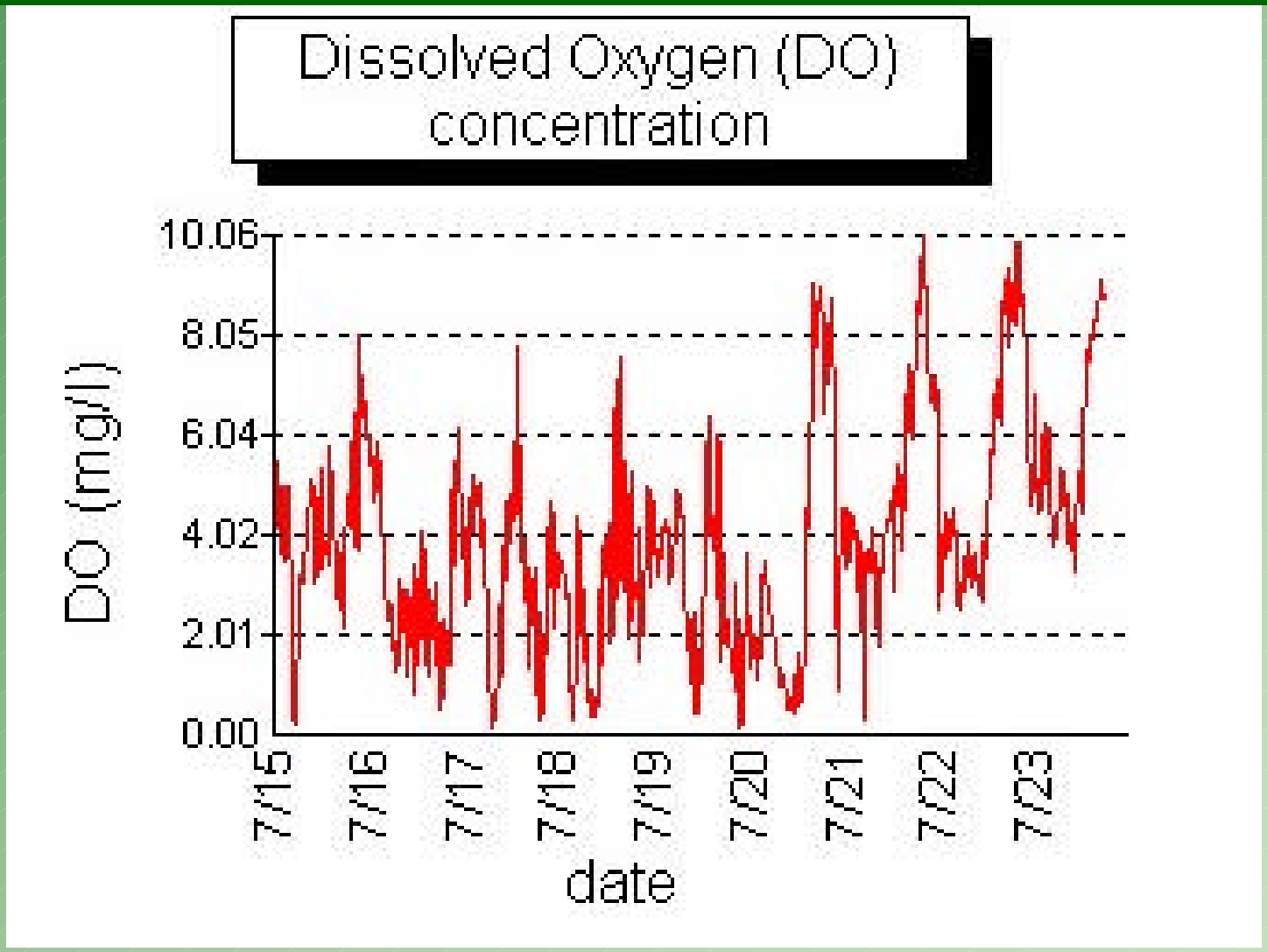
# Shallow Water Monitoring

# Rationale for Shallow-Water Monitoring Design

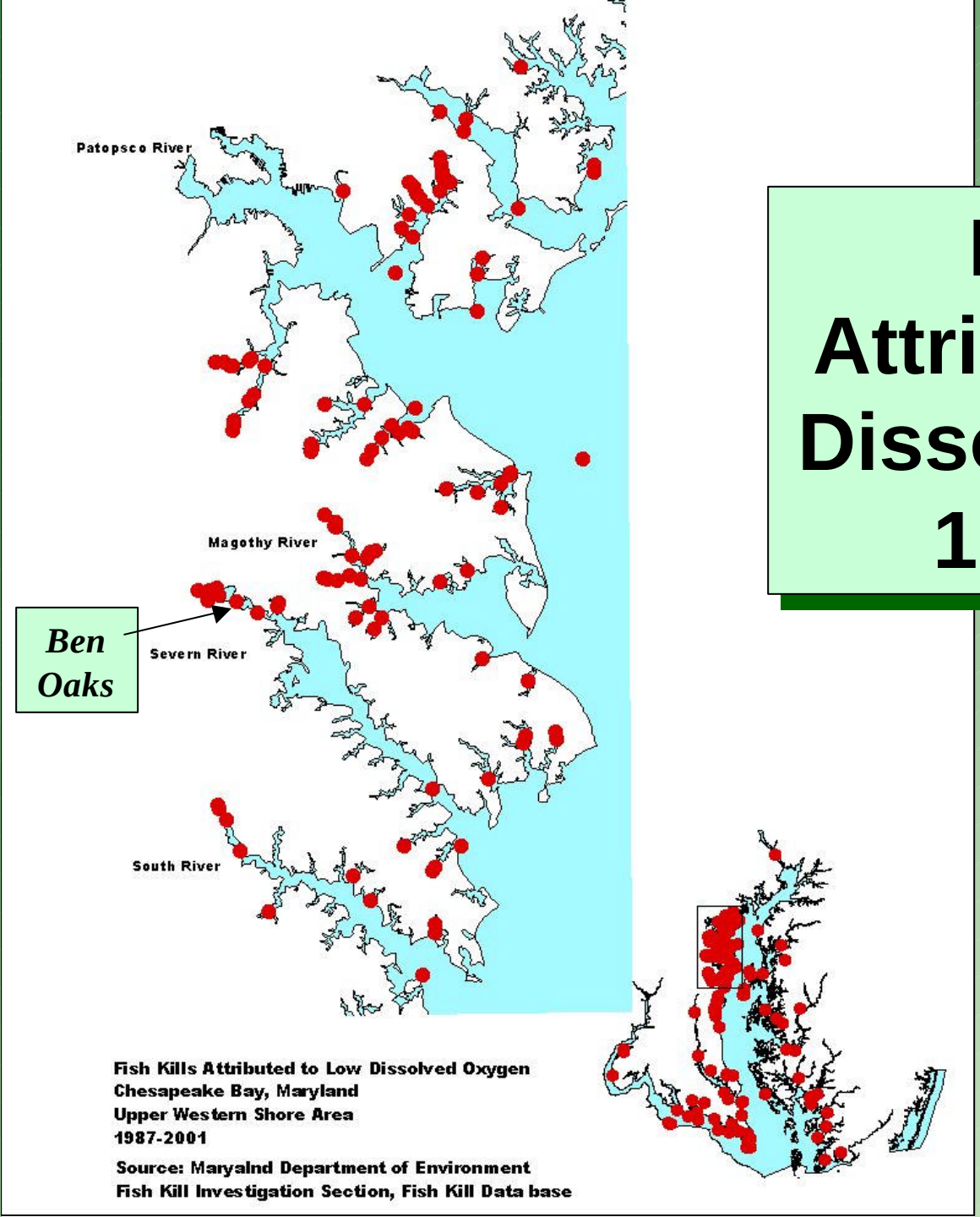
- Little Prior Knowledge
- Can be Extremely Dynamic
- High Spatial Variability
- Critical Habitat
- Most Fish Kills

# Buoy Data for Continuous DO Measurements

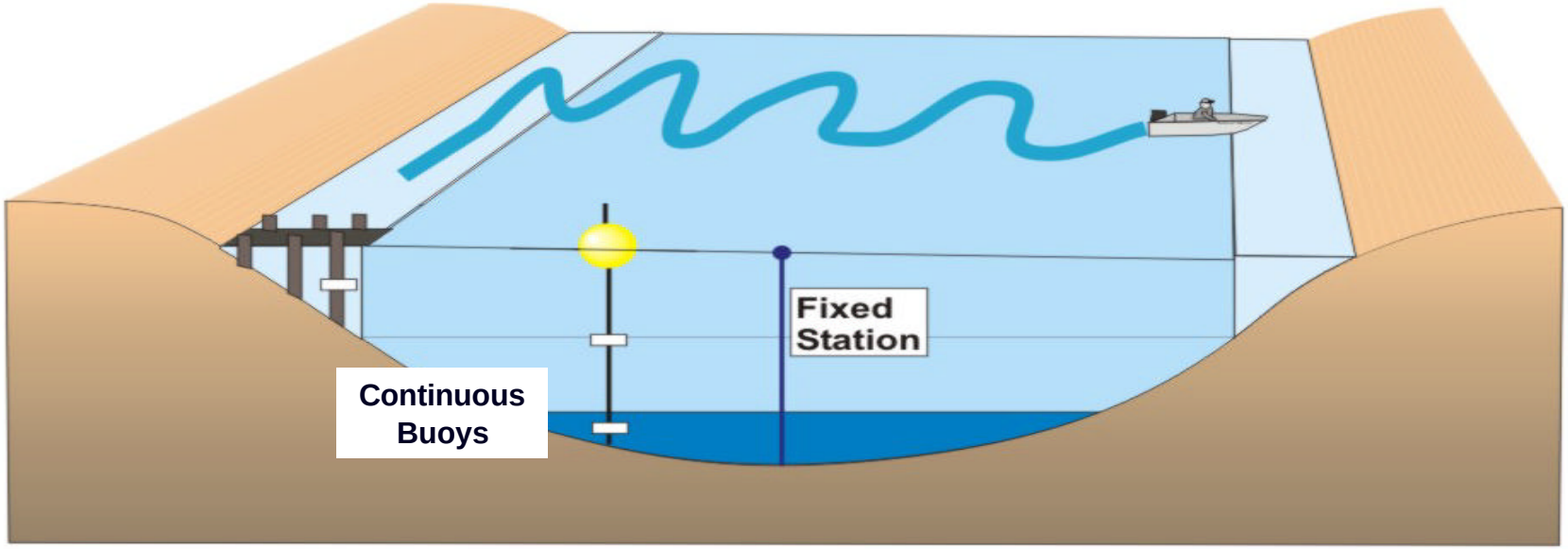
## Severn River at Ben Oaks



# Fish Kills Attributed to Low Dissolved Oxygen 1987 - 2001



# Medium Tributary

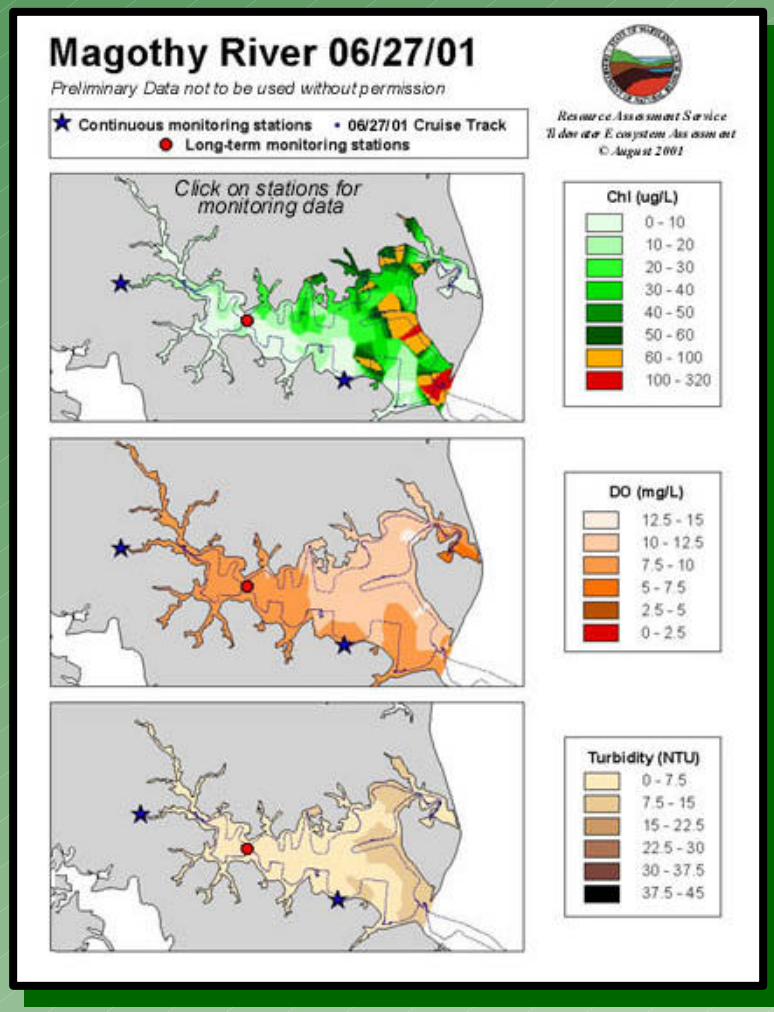


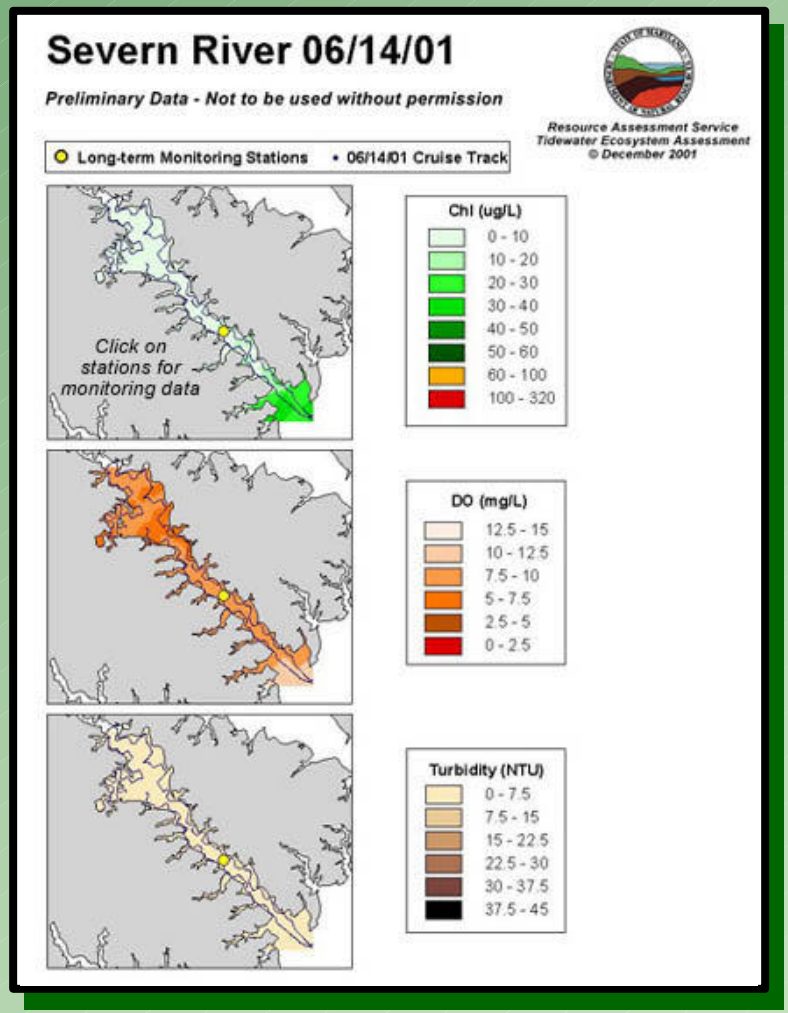

- Existing Fixed Stations
- Spatially Intensive Data Collection
- Continuous Buoys

# *Components of Shallow-Water Monitoring Design*

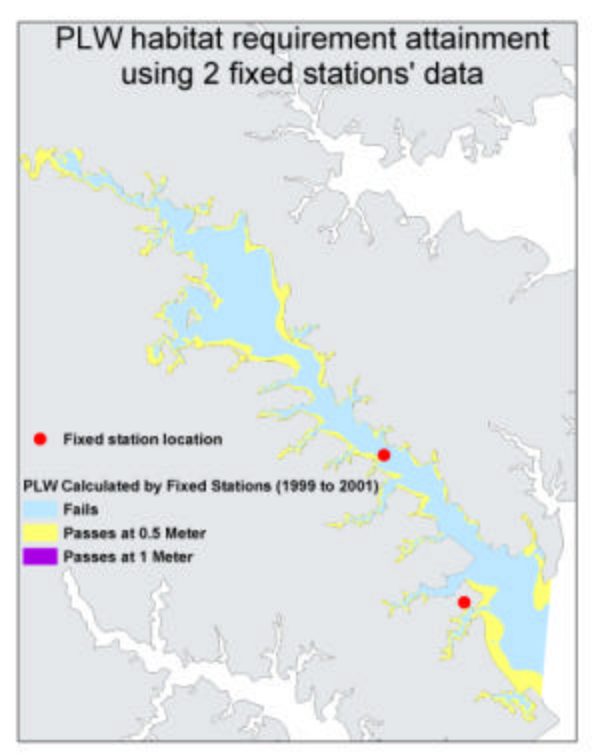
- Fixed-Station Continuous – Temporally Intensive
  - **Dissolved oxygen**
  - **Fluorescence**
  - **Turbidity**
  - **Water temperature**
  - **Salinity**
  - **pH**
- Water-Quality Mapping – Spatially Intensive
  - **Dissolved oxygen**
  - **Fluorescence**
  - **Turbidity**
  - **Water temperature**
  - **Salinity**

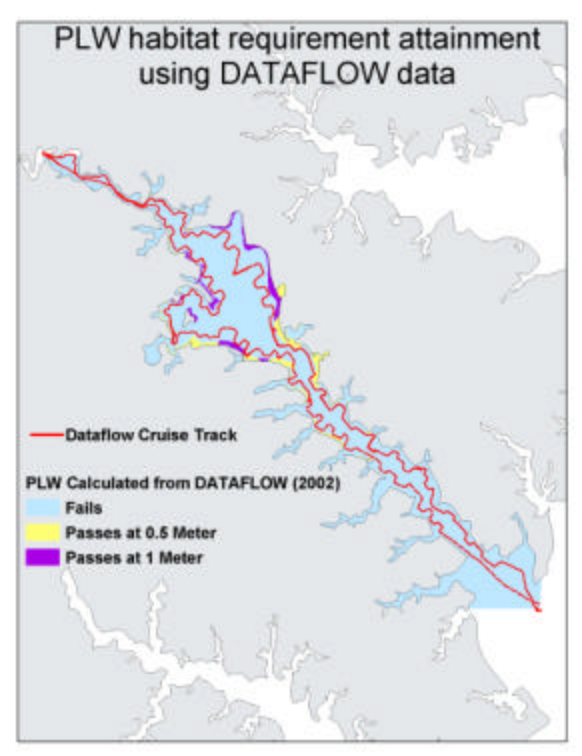
# Continuous Underway Monitoring

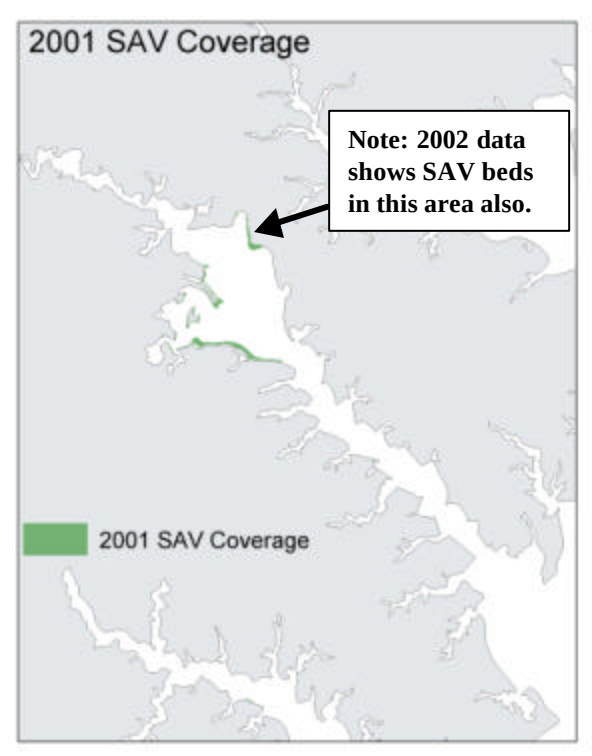


# Value of Water Quality Mapping for Identifying SAV Habitat



# Current Shallow-Water Monitoring Plans

- Current Funding Allows for Shallow-Water Monitoring in 16 (out of ~ 100) Segments
- Selected Segments Include 10 in MD, 6 in VA
  - Maryland – Severn, Magothy, Patuxent, Bush, Gunpowder, Middle, Chicamacomico and Chester
  - Virginia – York, Mattaponi, Pamunkey
- At the Current Rate, A Full Assessment Will Not Be Completed Until 2020

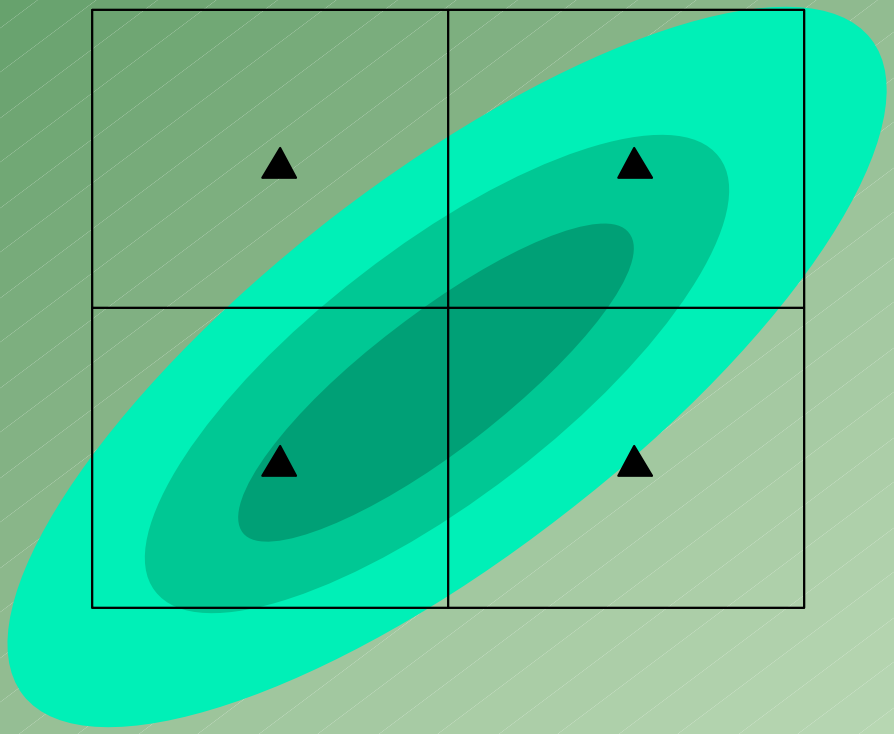
# Rationale for Criteria Assessment Approach

# Monitoring for Criteria Assessment

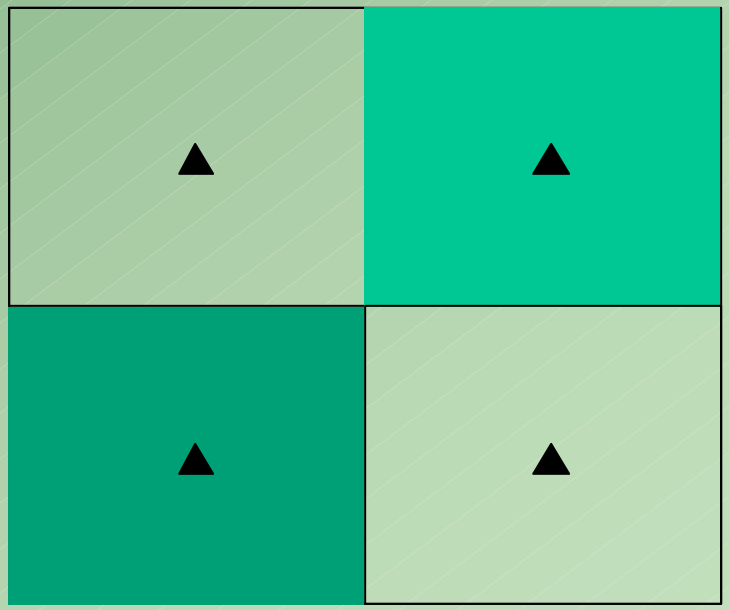
## Conceptual Example 1 - One Fixed Station per Segment

Fixed-Station Network

Actual Spatial Distribution of Parameter



Assessment Based on 10% Rule

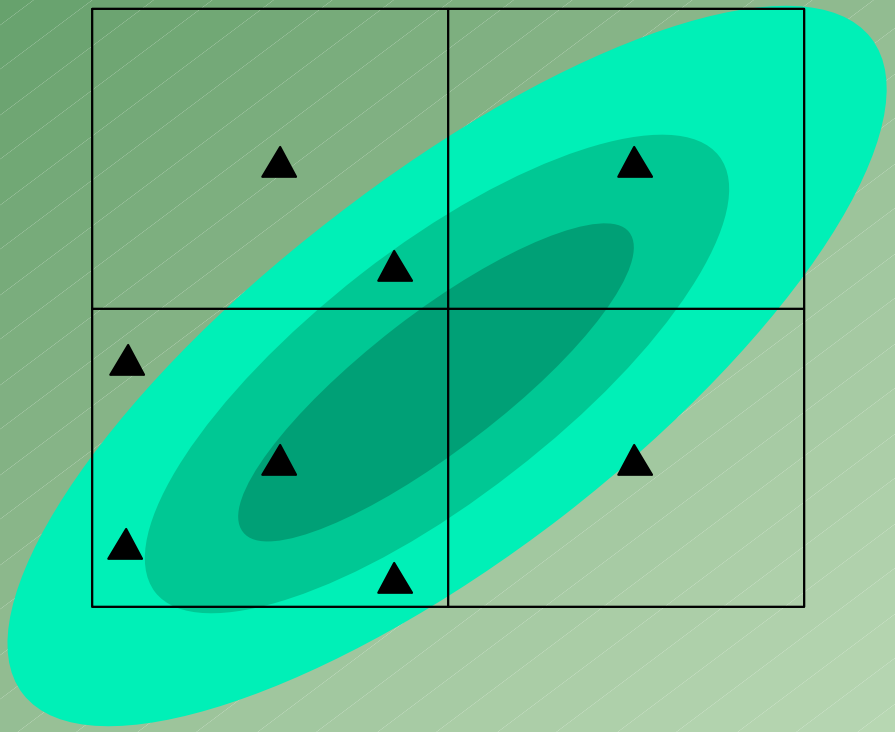


# Monitoring for Criteria Assessment

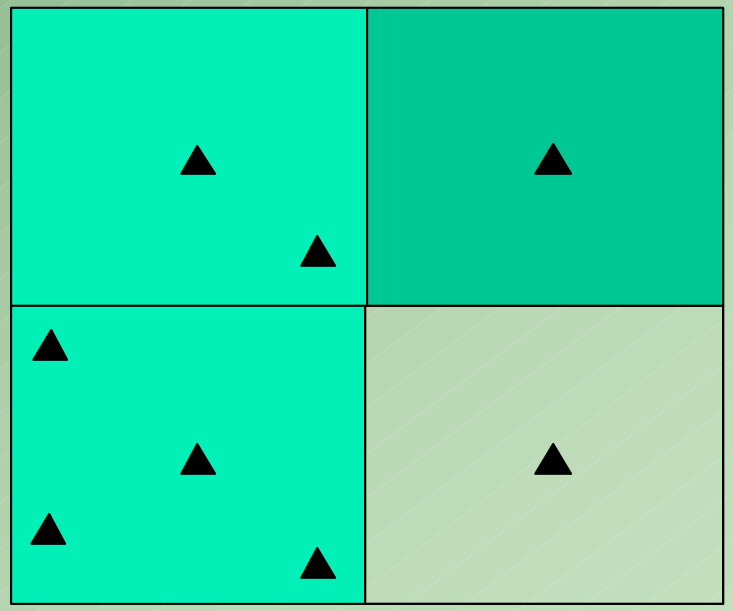
## Conceptual Example 2 - Multiple Fixed Stations per Segment

Fixed-Station Network

Actual Spatial Distribution of Parameter



Assessment Based on 10% Rule

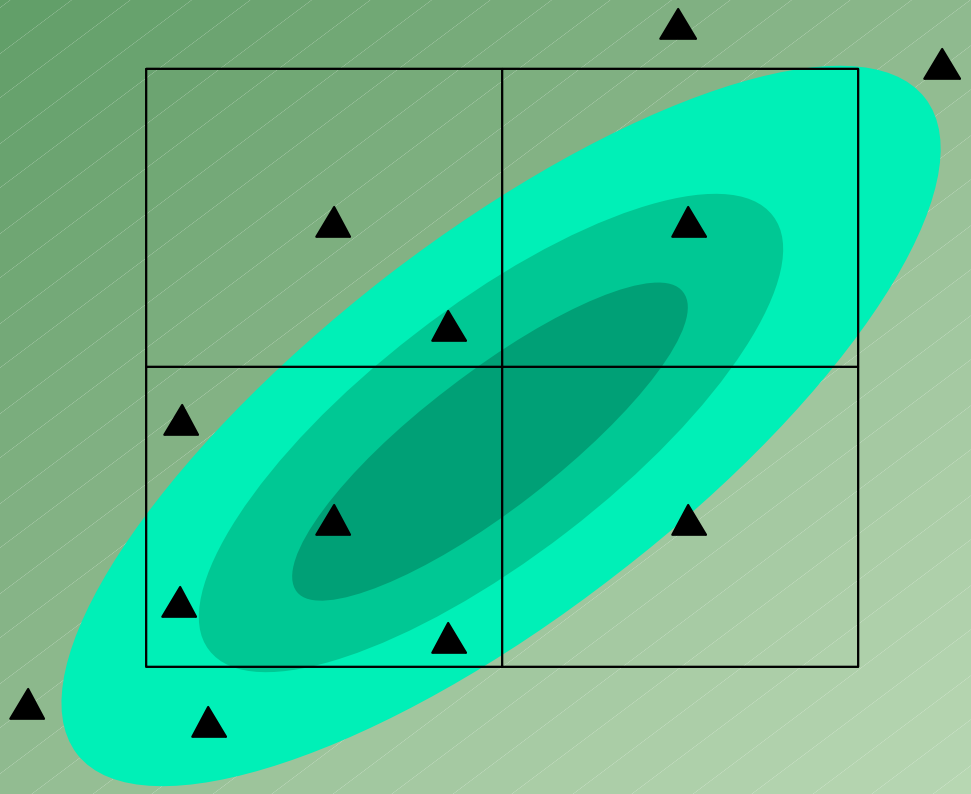


# Monitoring for Criteria Assessment

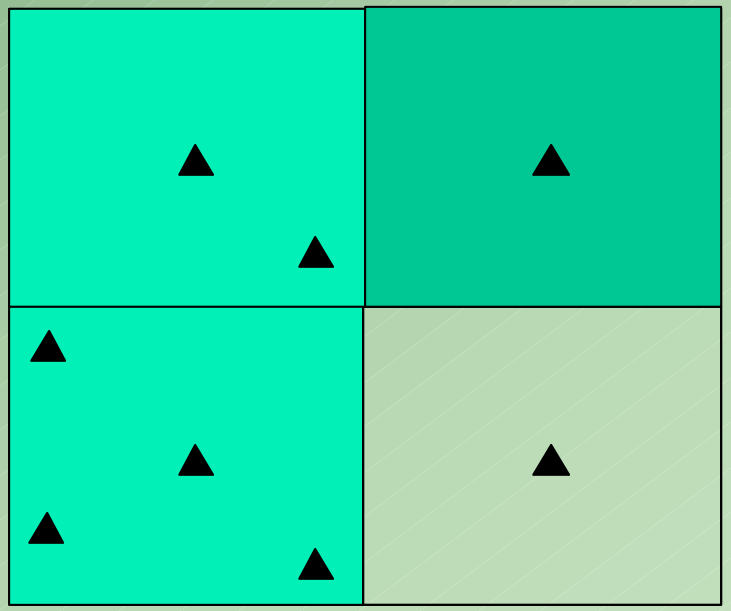
## Conceptual Example 3 – Use of Stations Outside of Segment

Fixed-Station Network

Actual Spatial Distribution of Parameter



Assessment Based on 10% Rule

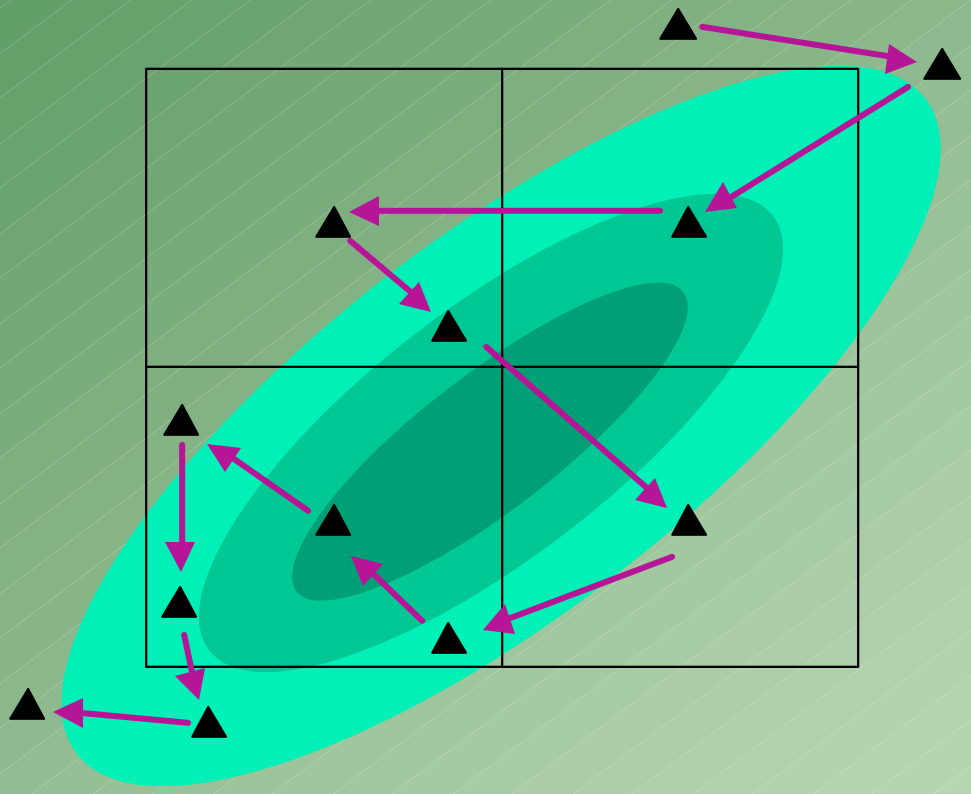


# Monitoring for Criteria Assessment

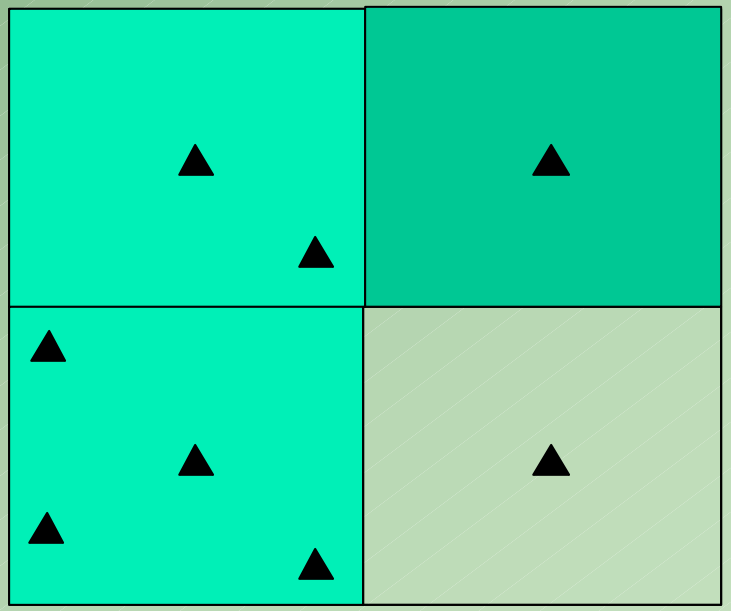
## Conceptual Example 4 – Use of New Technologies

Fixed-Station Network

Actual Spatial Distribution of Parameter



Assessment Based on 10% Rule



# Analytical Approach for Criteria Assessment

# Approach for Defining Attainment of Criteria and Designated Uses

1. Develop an analytical tool that uses available data to account for spatial and temporal variability in criteria exceedence.

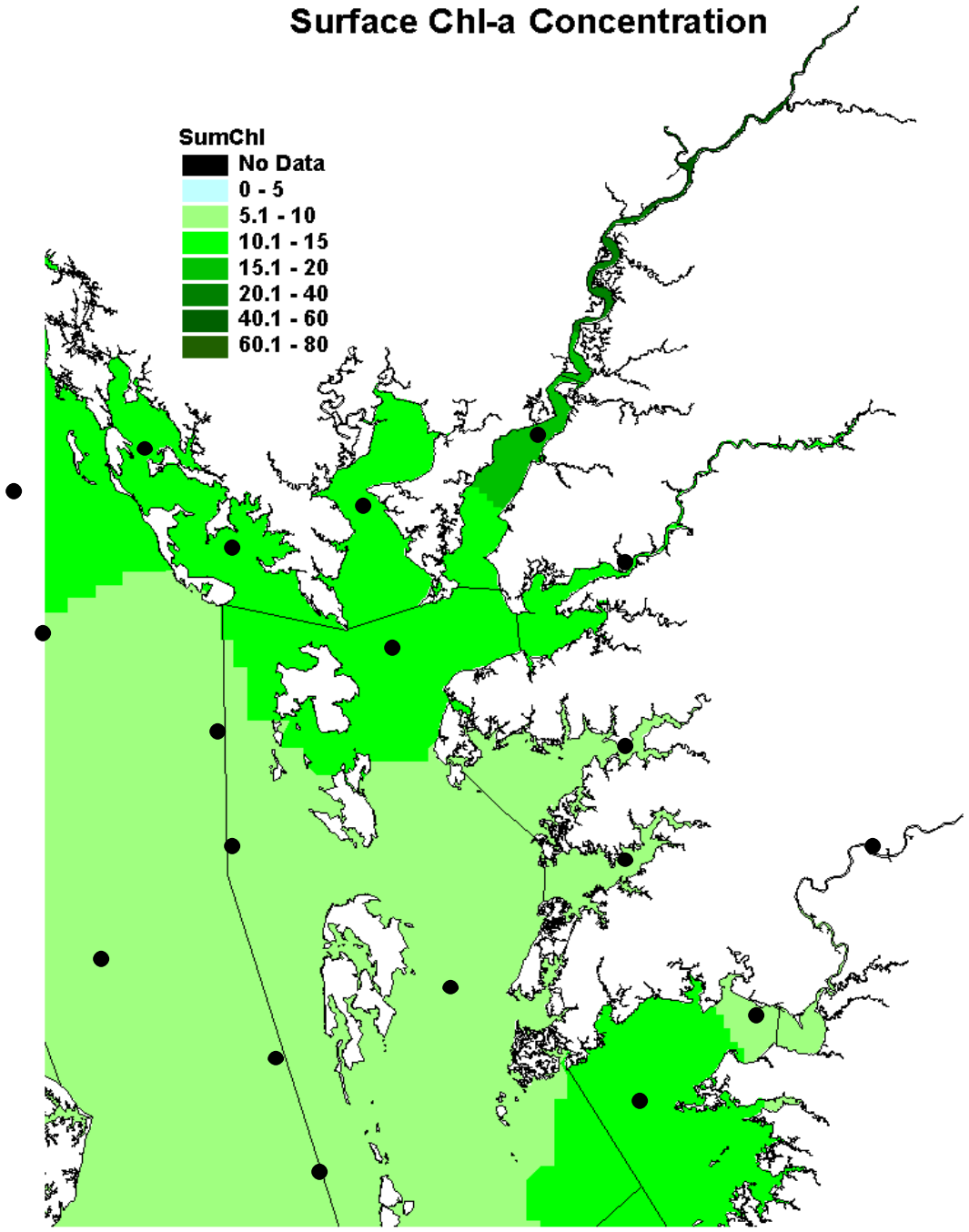
2. Analytical tool should be able to incorporate and benefit from different types of data including data collected using new technologies.

3. Analytical tool should provide a precise rule for deciding if a given segment is attaining its designated use.

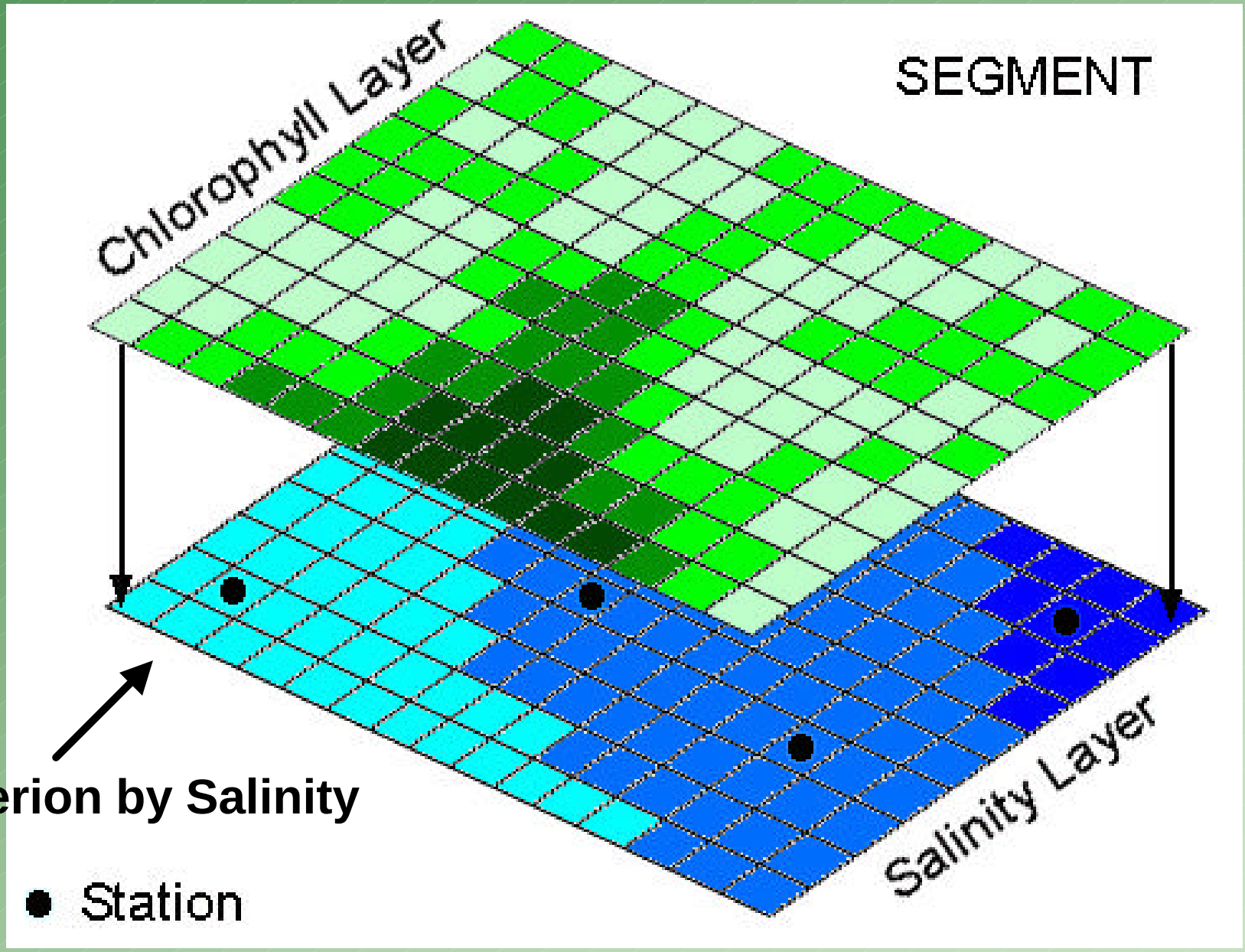
# Steps for Developing a CFD

**Step 1: Interpolate the Bay water quality monitoring data for each sampling event (e.g., cruise)**

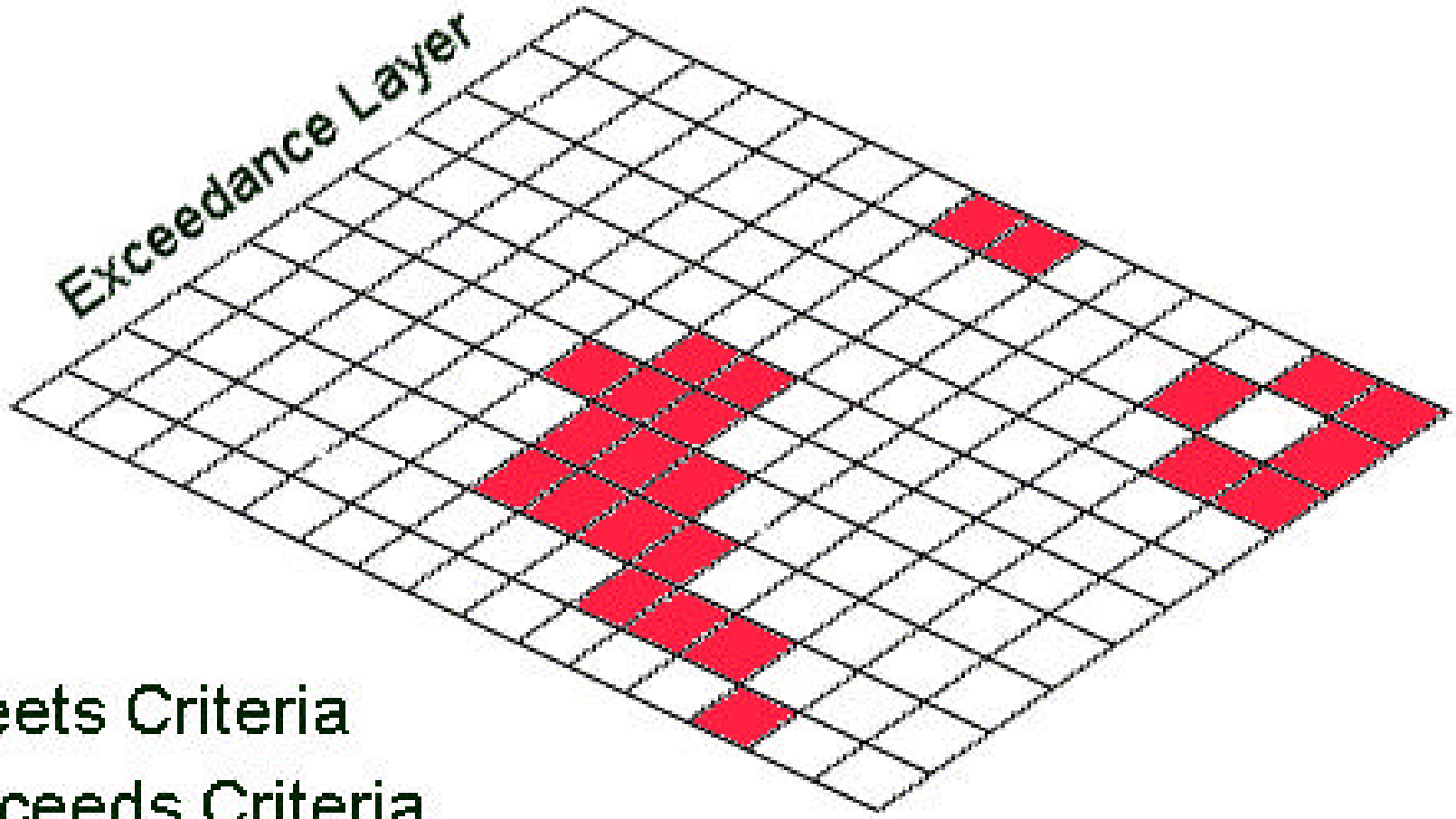
- Station



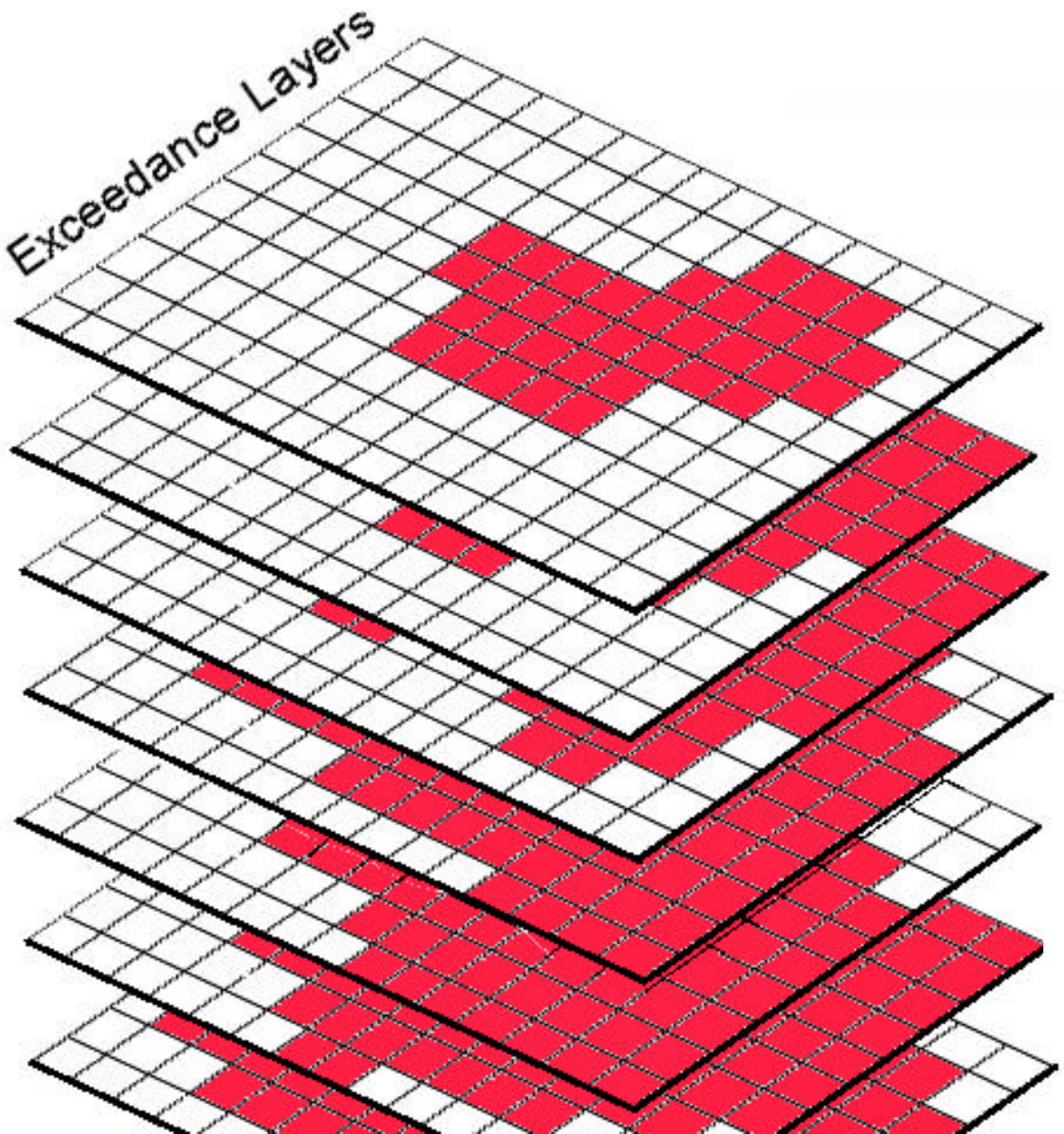
**Step 2. Evaluate interpolated WQ monitoring data interpolator cell by cell using the appropriate criterion value**



# Step 3. Identify the cells in a CBP segment / designated use area that exceed the criteria for each sampling event



## Step 4. Repeat Step 3 for each sampling event in assessment period ...




March 1999

April 1999

May 1999

June 1999

March 2000

Apr 2000

May 2000

Assessment Period

**Step 5. Compile the measures of % area (%volume) exceeding the criteria. This quantifies the SPATIAL EXTENT of the exceedences in a segment for each sampling event.**

**Example Assessment Over A Three Year Assessment Period**

| Month | % Area (%Volume) Exceeding |
|---|---|
| Mar-98 | 72.0000 |
| Apr-98 | 55.0000 |
| May-98 | 65.0000 |
| Jun-98 | 75.0000 |
| Mar-99 | 49.0000 |
| Apr-99 | 34.0000 |
| May-99 | 67.0000 |
| Jun-99 | 25.0000 |
| Mar-00 | 20.0000 |
| Apr-00 | 39.0000 |
| May-00 | 35.0000 |
| Jun-00 | 50.0000 |

## Step 6. Sort and rank the measures of % area/volume of criteria exceedence

**Example Assessment Over A Three Year Assessment Period**

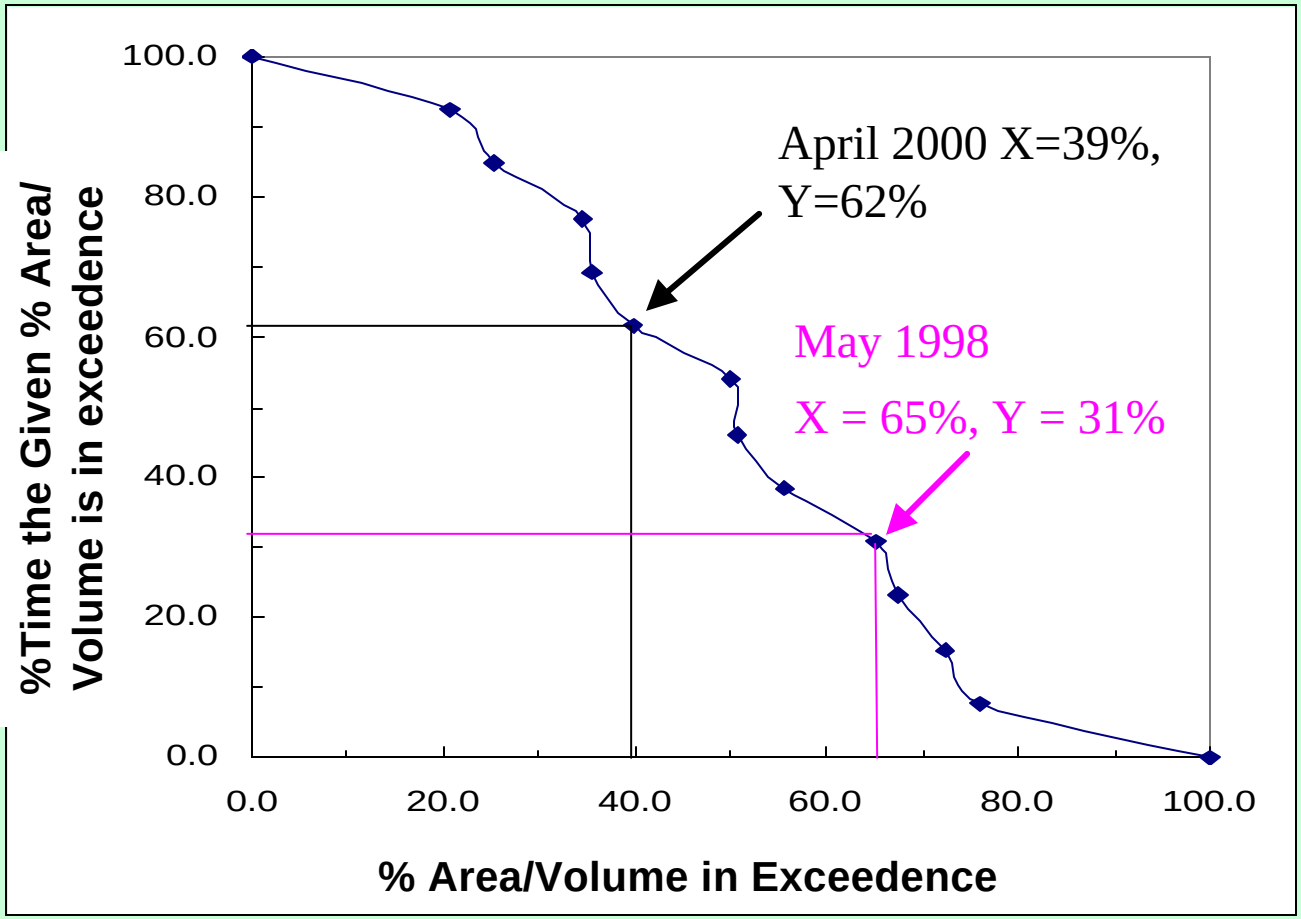
| Month | % Area (%Volume) Exceeding | Rank |
|---|---|---|
| Jun-98 | 75.0000 | 1 |
| Mar-98 | 72.0000 | 2 |
| May-99 | 67.0000 | 3 |
| May-98 | 65.0000 | 4 |
| Apr-98 | 55.0000 | 5 |
| Jun-00 | 50.0000 | 6 |
| Mar-99 | 49.0000 | 7 |
| Apr-00 | 39.0000 | 8 |
| May-00 | 35.0000 | 9 |
| Apr-99 | 34.0000 | 10 |
| Jun-99 | 25.0000 | 11 |
| Mar-00 | 20.0000 | 12 |

## Step 6. Calculate the cumulative probability values based on the ranks

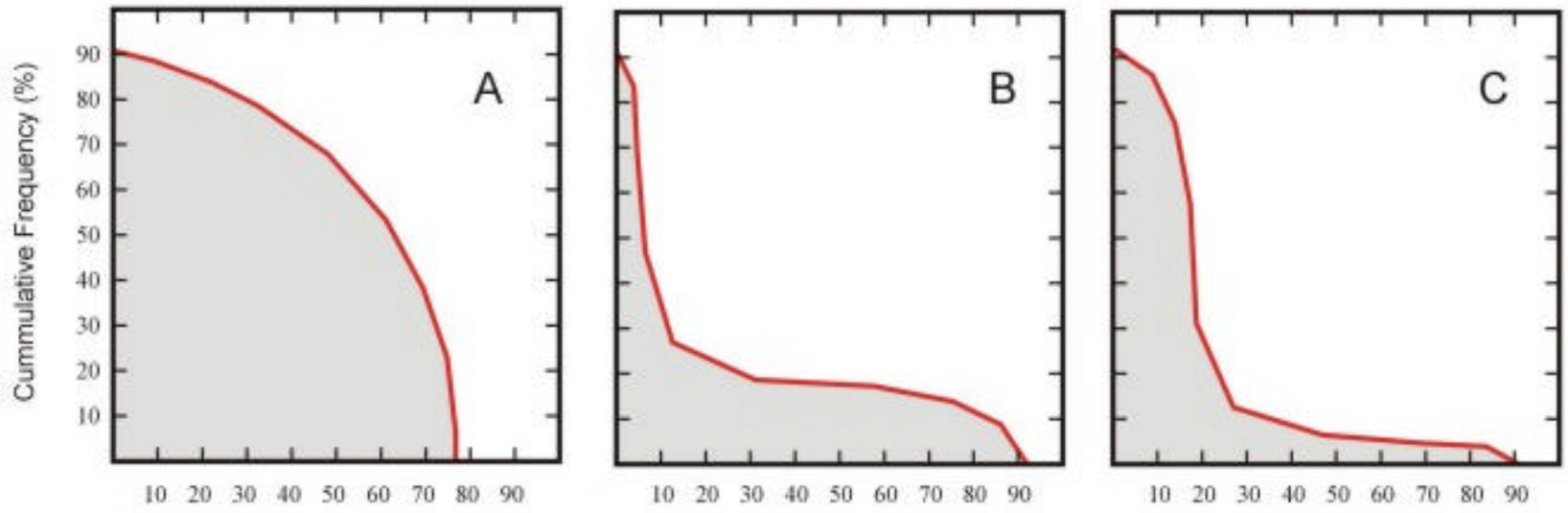
| Month | % Area (%Volume) Exceeding | Rank | Cumulative Probability (Rank/n+1) |
|---|---|---|---|
| | 100.0000 | | 0.0000 |
| Jun-98 | 75.0000 | 1 | 7.6923 |
| Mar-98 | 72.0000 | 2 | 15.3846 |
| May-99 | 67.0000 | 3 | 23.0769 |
| May-98 | 65.0000 | 4 | 30.7692 |
| Apr-98 | 55.0000 | 5 | 38.4615 |
| Jun-00 | 50.0000 | 6 | 46.1538 |
| Mar-99 | 49.0000 | 7 | 53.8462 |
| Apr-00 | 39.0000 | 8 | 61.5385 |
| May-00 | 35.0000 | 9 | 69.2308 |
| Apr-99 | 34.0000 | 10 | 76.9231 |
| Jun-99 | 25.0000 | 11 | 84.6154 |
| Mar-00 | 20.0000 | 12 | 92.3077 |
| | 0.0000 | | 100.0000 |

## Step 7. Plot the % area in exceedence vs. cumulative probability over time

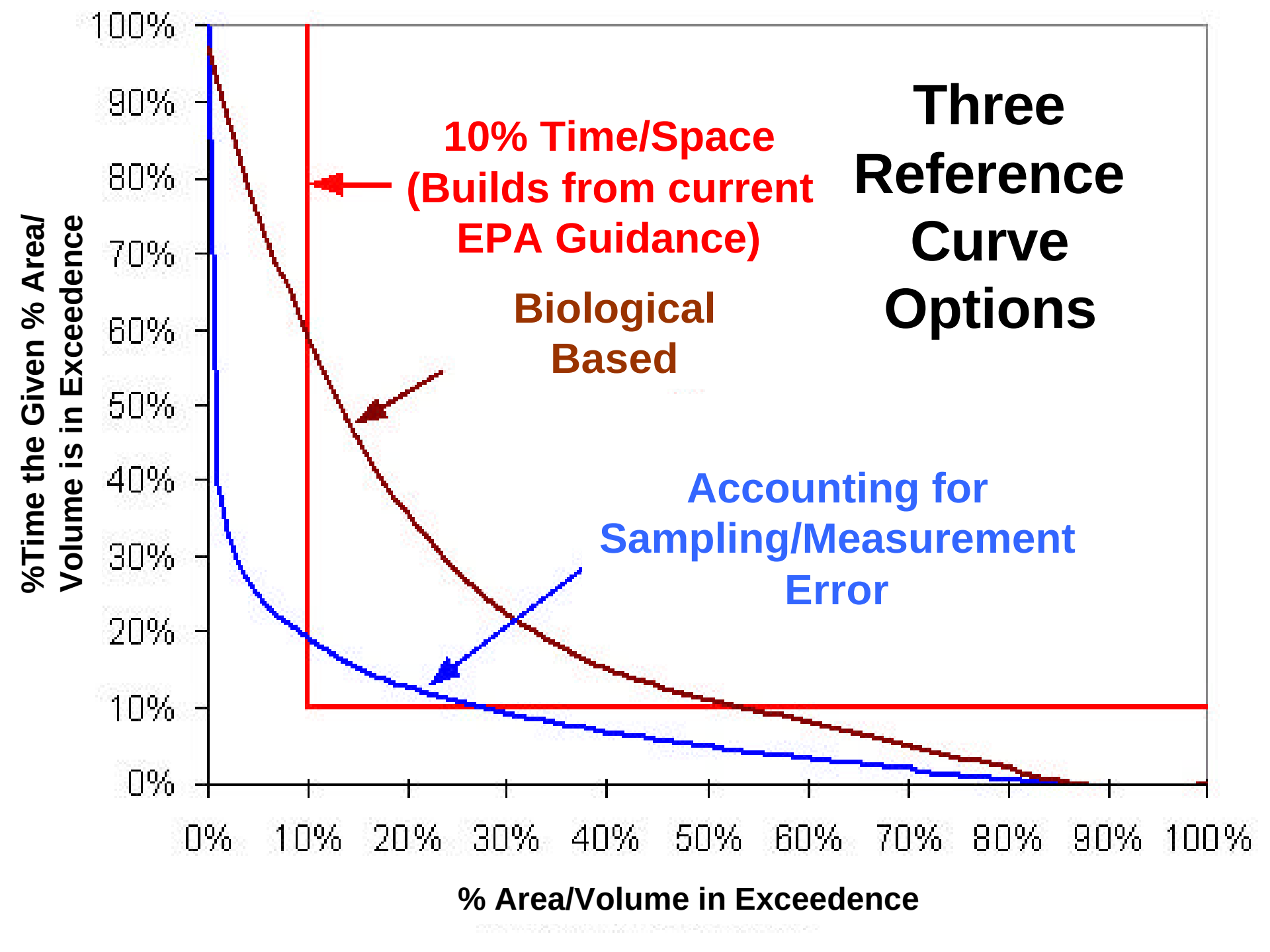
# Example Assessment Over A Three Year Assessment Period



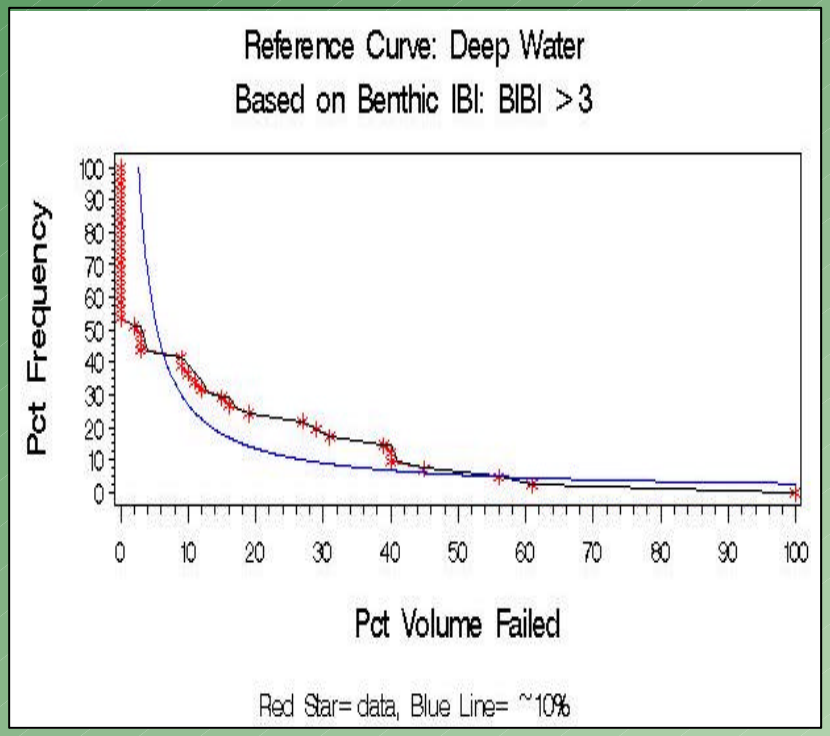
# Use of CFD's for Characterizing Spatial and Temporal Extent of Criteria Exceedence

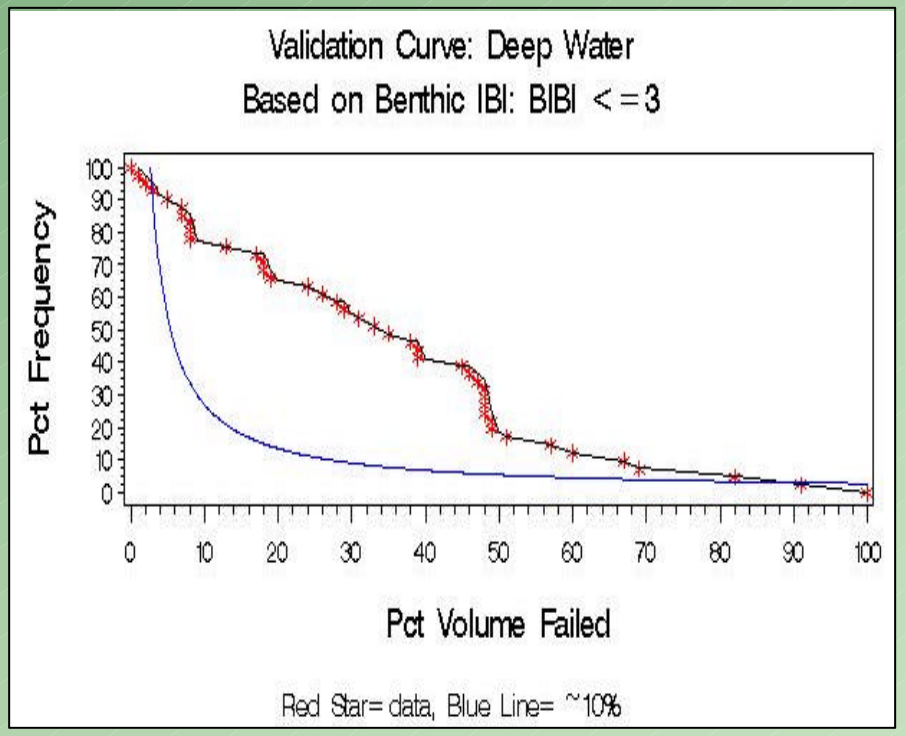


**Can we go beyond 10% towards something more reflective/protective of the living resources?**

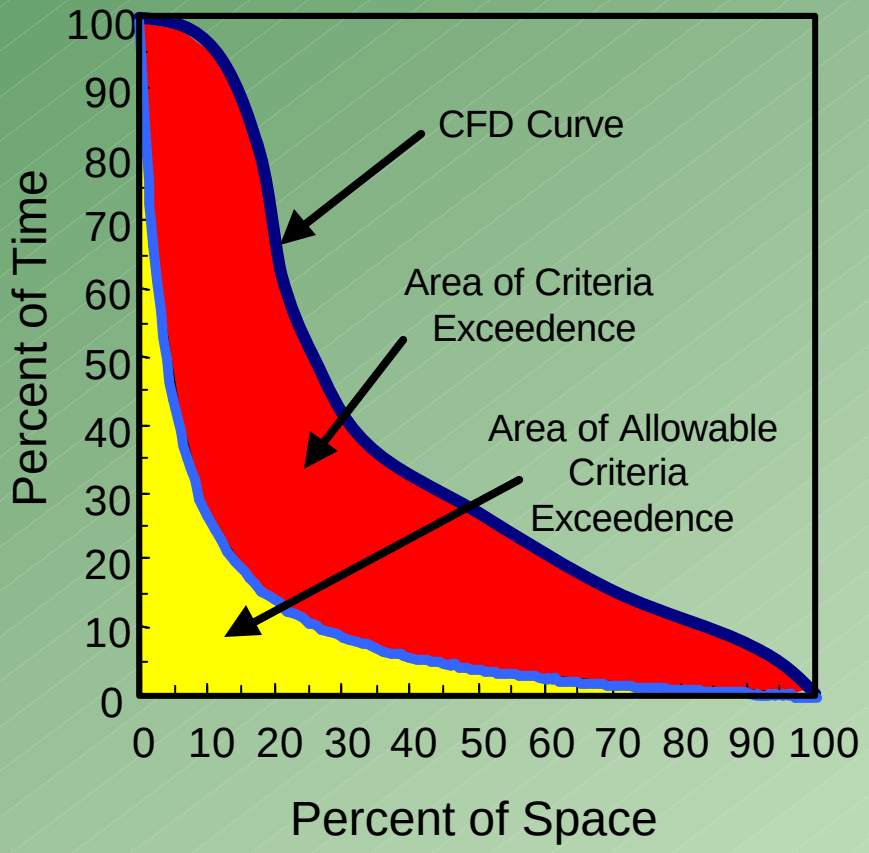

Three Reference Curve Options
10% Time/Space (Builds from current EPA Guidance)
Biological Based
Accounting for Sampling/Measurement Error
%Time the Given % Area/ Volume is in Exceedence
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% Area/Volume in Exceedence

# Deep Water Dissolved Oxygen Criteria Reference Curve

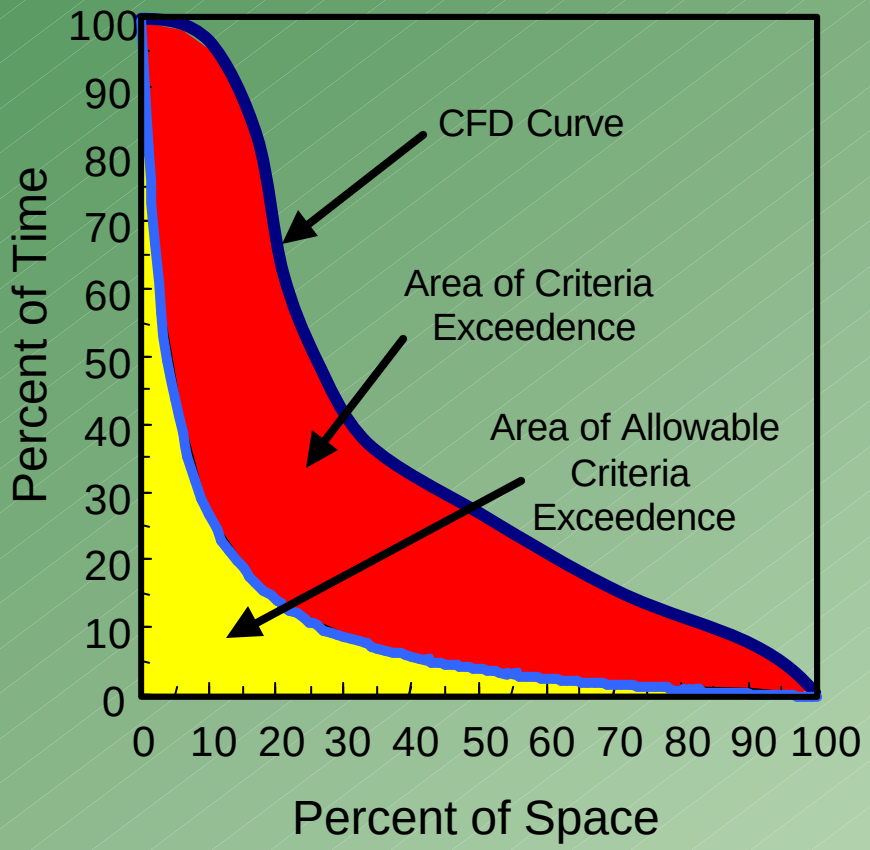


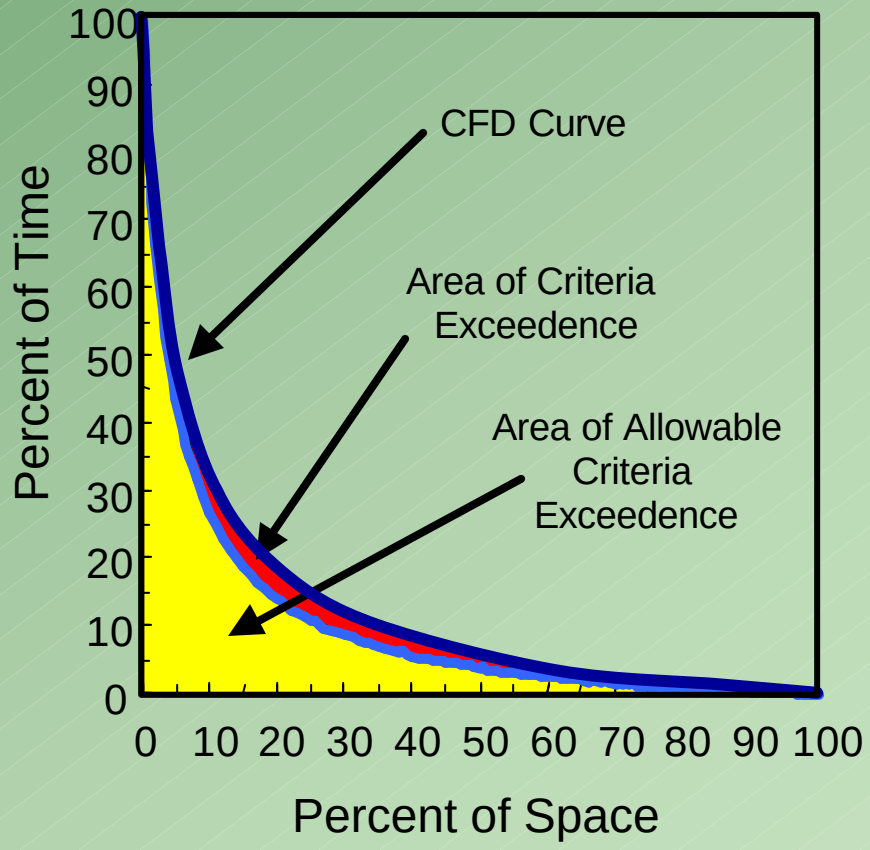



# Definition of Attainment

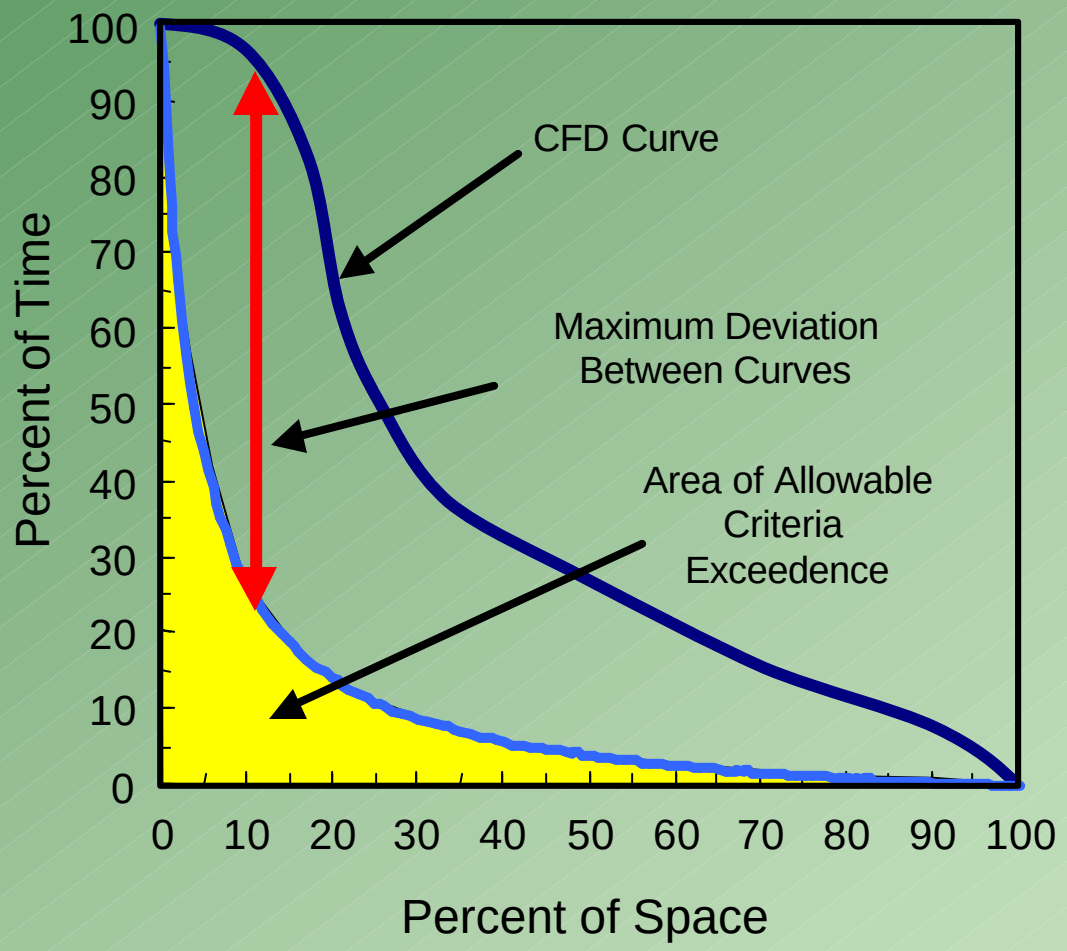


# Definition of Attainment:
## Any Excursion Above the Reference Curve



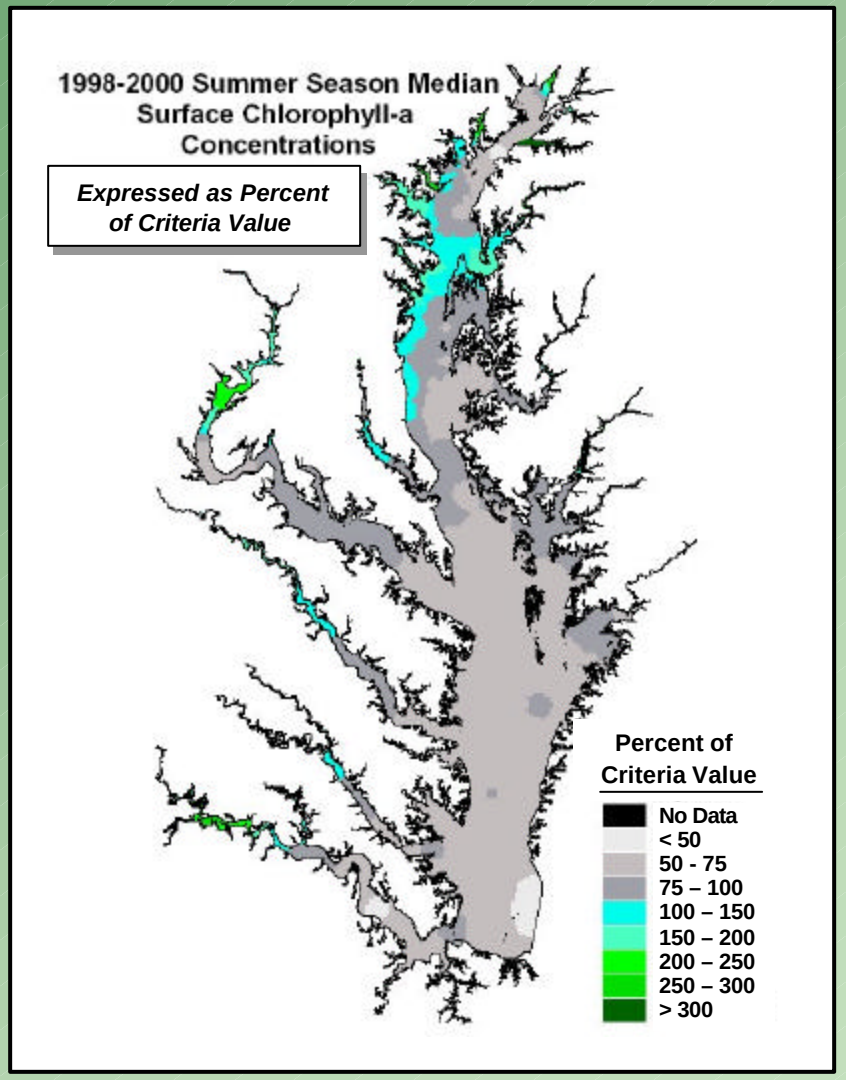



# Definition of Attainment
## Kolmogorov-Smirnov Test



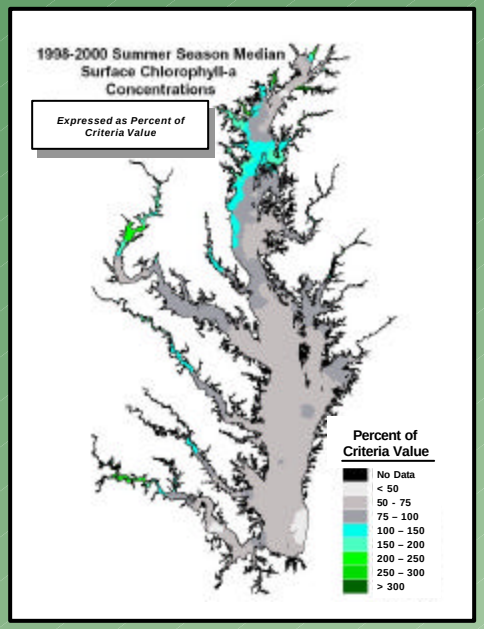
# Map Magnitude of Exceedence

Express criteria exceedence in terms of percent of criteria value evaluated over the assessment period and illustrated spatially

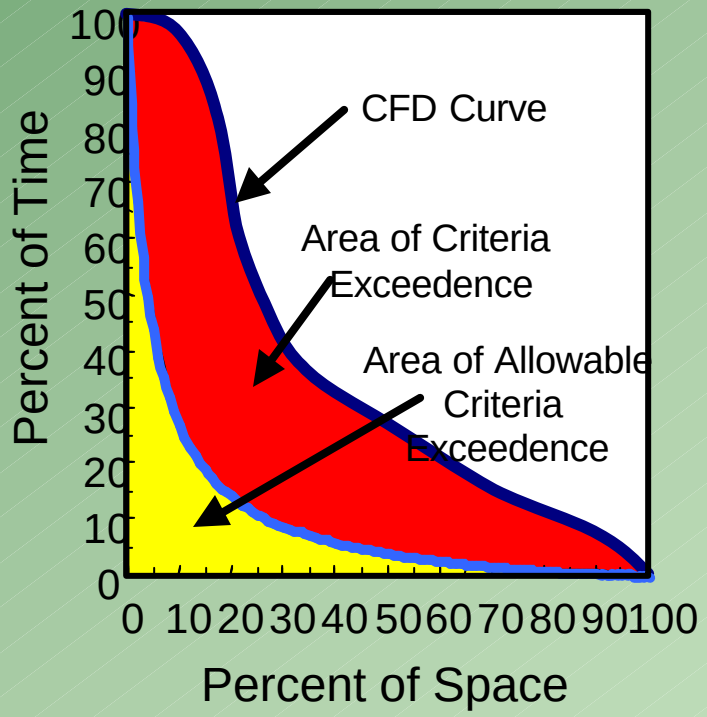


# Tools For Defining Attainment

Magnitude of Exceedence




Spatial and Temporal Extent of Exceedence




Statistical Significance

Statistical Test